adsorbents preparation. J.C., Z.Z., Y.S., J.W., Y.Z., B.M., Y.Z., and J.W. performed the characterization. Z.Y., J.C., L.Y., and J.H. performed the simulated calculations. J.C., L.Y., H.X., and X.C. analyzed the data and wrote the paper. **Competing interests:** The authors declare no competing financial interests. The authors and their affiliated institutions have a patent pending related to the results presented here. **Data and materials availability:** All data are available in the manuscript or the supplementary materials. The related CIF of ZU-609, ZU-609 after refinement and ZU-609 loaded with C_3H_6 have been uploaded to the Cambridge crystallographic data center (CCDC 2266913, 2277294, and 2277295).

SUPPLEMENTARY MATERIALS

science.org/doi/10.1126/science.abn8418
Materials and Methods
Supplementary Text
Figs. S1 to S41
Tables S1 to S14
References (*51*–*55*)
Data S1 and S2

Submitted 23 December 2021; resubmitted 5 July 2023
Accepted 1 December 2023
Published online 14 December 2023
10.1126/science.abn8418

ANTHROPOLOGY

Two thousand years of garden urbanism in the Upper Amazon

Stéphen Rostain[1]*, Antoine Dorison[2], Geoffroy de Saulieu[3], Heiko Prümers[4], Jean-Luc Le Pennec[5], Fernando Mejía Mejía[6], Ana Maritza Freire[7], Jaime R. Pagán-Jiménez[8], Philippe Descola[9]

A dense system of pre-Hispanic urban centers has been found in the Upano Valley of Amazonian Ecuador, in the eastern foothills of the Andes. Fieldwork and light detection and ranging (LIDAR) analysis have revealed an anthropized landscape with clusters of monumental platforms, plazas, and streets following a specific pattern intertwined with extensive agricultural drainages and terraces as well as wide straight roads running over great distances. Archaeological excavations date the occupation from around 500 BCE to between 300 and 600 CE. The most notable landscape feature is the complex road system extending over tens of kilometers, connecting the different urban centers, thus creating a regional-scale network. Such extensive early development in the Upper Amazon is comparable to similar Maya urban systems recently highlighted in Mexico and Guatemala.

Urbanism and Amazonia are rarely associated when we evoke pre-Hispanic times. However, Francisco de Orellana, leading an expedition down the great river in 1541–42, witnessed large cities along its banks (*1*) yet was called a fabulist upon his return. More than four centuries later, in the 1980s, great archaeological sites with thick layers of Amazonian dark earth were discovered in the middle Amazon, confirming the existence of extensive pre-Hispanic settlements along the river (*2*). Orellana did not lie.

Recently, various monumental archaeological sites were brought to light in Amazonia (*3*, *4*). Some of them display earthen platforms of various sizes with a variety of features, including causeways, mounds, canals, and/or fortifications [as in the Barinas llanos in Venezuela (*5*), the Llanos de Mojos in Bolivia (*6*), and the Upper Xingu and central Amazon in Brazil (*7*–*9*)] or roads [as in southwestern Amazonia (*10*, *11*)]. Pre-Hispanic inhabitants of the Amazon were indeed remarkable land builders who intensively reworked their environment, thus changing the morphology of their territories (*12*–*14*) and its vegetation cover (*15*, *16*).

Here we present an extensive case of a pre-Hispanic urban system in the Amazon region. Located in the Upper Amazon on the eastern slopes of the Ecuadorian Andes, its dense population extended across the high alluvial terraces that border the Upano River (*17*). The data of this study stem from more than two decades of interdisciplinary investigations in the region, the scope of which was recently broadened by light detection and ranging (LIDAR) mapping in a 300-km^2 area. This research revealed the largest urban network of erected and excavated features known in Amazonia, whose beginnings date back to 2500 years ago (*18*). This discovery raises many questions, among them the following: What types of features were built by the pre-Hispanic inhabitants? Were the settlements contemporary and connected to each other? Where did the inhabitants cultivate the large quantity of plants needed for their subsistence?

Context

Stretching along the foothills of the Andes in southern Ecuador, enclosed between the Andes to the west and the Cutucú range to the east, the Upano Valley is a region where Amazonian and Andean ecosystems meet, with an important seismic risk—the earthquake of 1995 reached a moment magnitude of 7.0 (*19*). Towering above it, the active Sangay stratovolcano, a steep-sided, cone-shaped, snow-capped mountain, peaks at 5230 m above sea level. After descending the Andean slopes, the Upano River goes straight south along the sub-Andean Range (*20*).

Groups of earthen platforms have been archaeologically explored: They form large settlements extending over the 70- to 100-m-high alluvial terraces along the river (Fig. 1). Few sites have been excavated (*21*–*24*). One of the largest settlements, Sangay, was discovered in the late 1970s and excavated by three successive teams (*17*, *25*, *26*). Started in the mid-1990s, the Upano interdisciplinary project brought together archaeologists, geoscientists, and archaeobotanists to investigate the entire valley. The scope of the fieldwork results, which have led to a better understanding of the valley's earthworks, has recently been broadened by LIDAR survey.

Our fieldwork led to results concerning the pre-Hispanic cultural sequence, habitat and diet, and the ancient volcanic activity and morphogenesis of the valley. Archaeological work focused on mounds, central plazas, and roads, as well as sites without built features (supplementary text S1, figs. S1 to S6, and tables S1 and S2). Large-scale excavations in platforms and plazas at two major settlements (Sangay and Kilamope) revealed domestic floors, with postholes, caches, pits, hearths, large jars, grinding stones, and burnt seeds. The construction methods consisted of cutting the natural slope to form a base on which the mound was built (*27*). Intentional artifact deposits suggest that the building process was accompanied by ritual activities. The newly established dating sequence indicates the succession of at least five cultural ensembles. The original building of earthen platforms and roads took place between approximately 500 BCE and 300 to 600 CE and was carried out by groups from the Kilamope and later Upano cultures. Some mounds were then reoccupied, after a hiatus, by groups of the Huapula culture between 800 and 1200 CE (supplementary text S2 and fig. S7). All the evidence indicates a local cultural

[1]Archaeology of the Americas (UMR8096), French National Center for Scientific Research (CNRS), Paris, France. [2]Archaeology of the Americas (UMR8096), Paris-1 University, Paris, France. [3]Local Heritage, Environment and Globalization (UMR 208), French National Research Institute for Sustainable Development, Paris, France. [4]Kommission für Archäologie Außereuropäischer Kulturen, Bonn, Germany. [5]Geo-Ocean, Brest University, CNRS, Ifremer, Institut Universitaire Européen de la Mer (UMR6538), French National Research Institute for Sustainable Development, Plouzané, France. [6]Anthropology and Archaeology Department, Pontifical Catholic University of Ecuador, Quito, Ecuador. [7]Museum of the Banco Central of Ecuador, Guayaquil, Ecuador. [8]Center for Social Research, University of Puerto Rico, San Juan, Puerto Rico. [9]Social Anthropology Laboratory, Collège de France, Paris Sciences et Lettres, Paris, France.
***Corresponding author. Email: stephen.rostain@cnrs.fr**

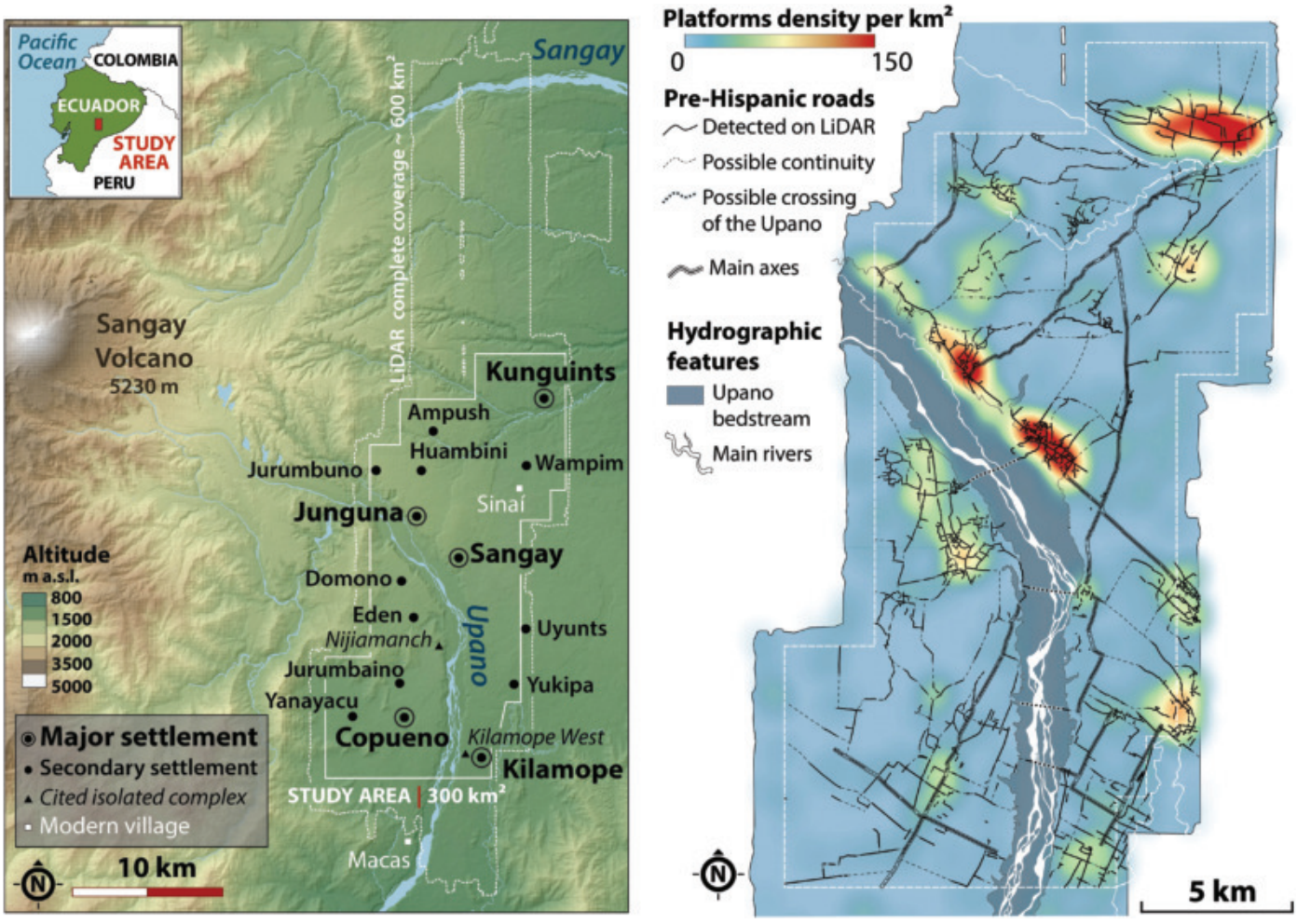

Fig. 1. Map of archaeological Upano Valley. (Left) Map of the Middle Upano with five major settlements and 10 secondary sites. m a.s.l., meters above sea level. (Right) Map of pre-Hispanic dug roads.

evolution process. There is no a priori reason to think that the pre-Hispanic inhabitants originated from the Andes and not from the Amazon.

The Kilamope and Upano people were sedentary agrarian societies that densely occupied the valley, where even today, according to local farmers, fertile volcanic soils still allow up to three harvests per year. Analyses of starch grains from potteries revealed the consumption of maize (*Zea mays*), beans (*Phaseolus* sp.), manioc (*Manihot esculenta*), and sweet potato (*Ipomoea batatas*). The microtraces on a maize starch grain are identical to those left today by the manufacture of the traditional "chewed" *chicha* (sweet beer), suggesting that this beverage may have been served in the Upano vessel (*28*). Upano pottery is well made and comes in many decorated types, the most common being the red-banded incised type with straight or curved painted and incised lines (*29*). Upano bowls and jars were exported up to the Andes, near the modern town of Cuenca (*30*).

Sangay volcano's intense activity had a definite impact on pre-Hispanic communities (*31*). Previous studies demonstrated continuous cone growth and two major flank failures during the Pleistocene (*32*). The resulting debris avalanches (*33*) spread as far as 60 km from the volcano (*34*) and left thick hummocky deposits, on which human settlements developed in late Holocene times. Analyses also indicate that large explosive eruptions occurred in the nearer past (*32*). The hypothesis that the Upano culture came to an abrupt end after a massive eruption ~400 to 600 CE has been raised (*18*) but has been called into question by the disparity of radiocarbon dates obtained recently for these levels.

LIDAR results

In 2015, the Ecuadorian National Institute for Cultural Heritage commissioned the LIDAR survey of a 600-km^2 area stretching from the Upper Upano to the Pastaza River to highlight anthropogenic features hidden under the canopy (*35*, *36*) (Fig. 1). After a 1-m-resolution digital elevation model had been derived from the point cloud, the Upano project team studied the 300-km^2 area constituting the southern part of this landscape (supplementary text S3, figs. S8 to S11, and table S3). The number and size of anthropogenic features led us to target only specific scientific goals. Given that previous fieldwork had already provided information on the internal organization of residential sites (*37*), we focused on the "gaps" between settlements and the road network rather than on intrasite features. This objective was also motivated by the identification in the field of various road starts (*38*). We set up a remote sensing methodology based on multiple LIDAR visualizations (*39*, *40*) (Fig. 2). Pre-Hispanic features were distinguished from modern elements according to their orientation and spatial coherence.

The analysis revealed an elaborate anthropogenic landscape. Settlements with standardized archaeological features evidencing a shared cultural background are interconnected by short-distance (intrasite) and long-distance (intersite) roads, which strongly suggests contemporaneity.

Platforms and plazas

The most common features are earthen platforms. Going far beyond the field identification

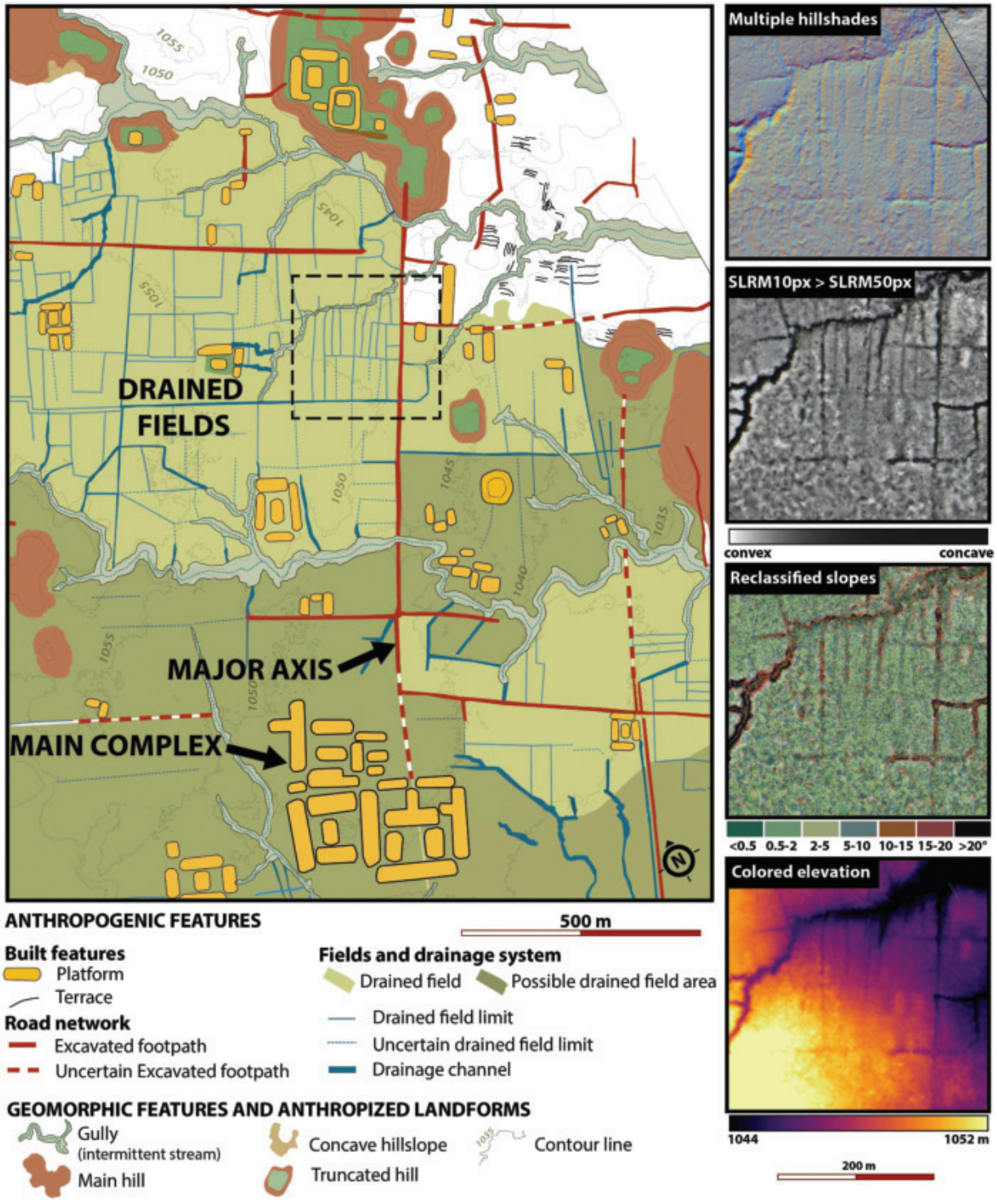

Fig. 2. Kilamope site. Anthropogenic features in the center of the Kilamope site, including residential platforms, dug footpaths, and agricultural structures. The four images on the right side of the figure illustrate different LIDAR visualizations used to interpret the digital elevation model in the same area (dotted rectangle) in order to highlight the drained-fields pattern. From top to bottom: hillshade from multiple directions, simple local relief models with 10- and 50-pixel radii overlaid, slopes reclassified according to geomorphological models (*40*), and color classification of the elevation.

of just some individual platforms, the LIDAR data enabled the detection of >6000 platforms within the 300-km^2 area. The standard shape is rectangular (although a few were circular) and about 20 m by 10 m with a preserved elevation of 2 to 3 m (Fig. 3).

Rarely isolated, the platforms typically occur in groups—or complexes—of three to six units around a plaza, often with a central platform. The most common complexes measure 40 m by 40 m (~1600 m^2) and are interpreted as 1residential (*37*). However, LIDAR imagery

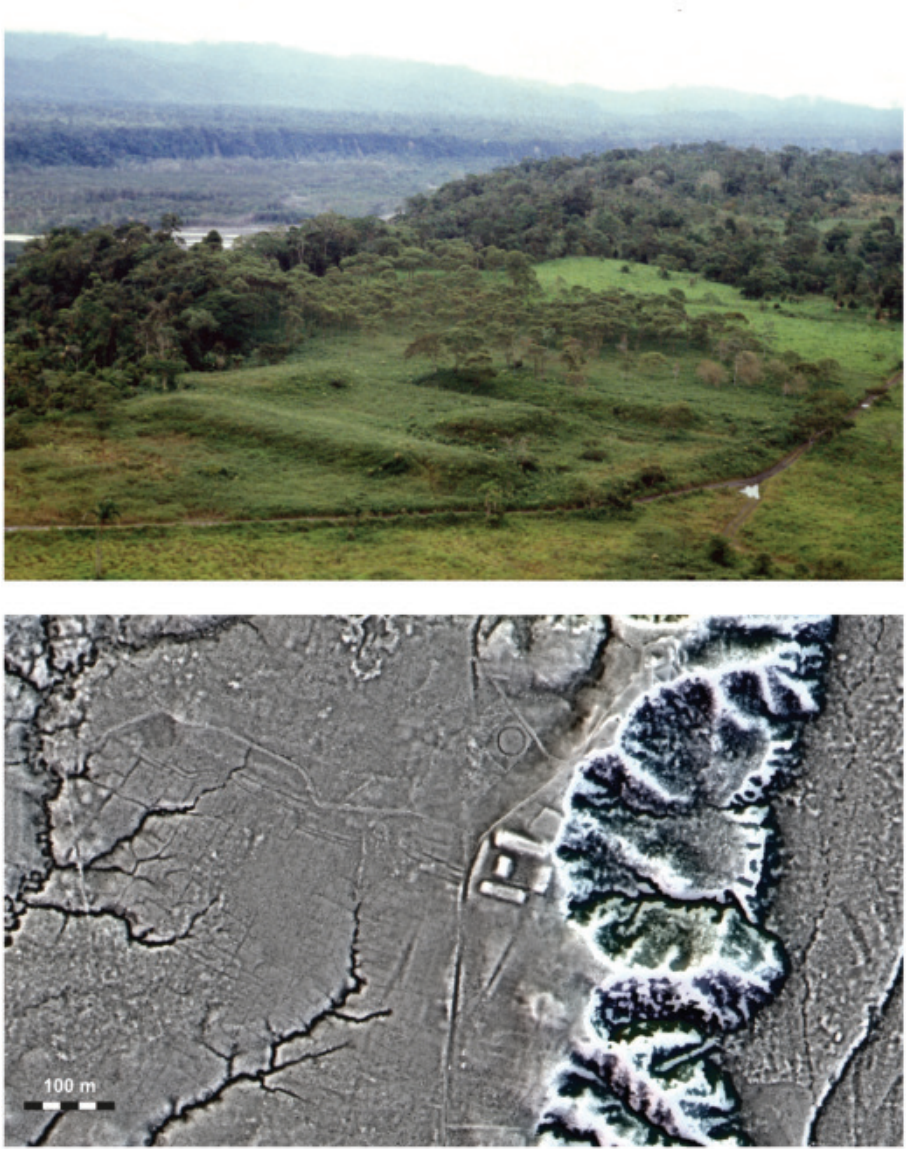

Fig. 3. Earth platforms complex. Earth platforms complex of Nijiamanch on the right bank of the Middle Upano. Drained fields are visible around the artificial mounds on the LIDAR image (bottom).

also highlighted monumental complexes probably bearing a civic-ceremonial function, with much larger platforms, but of similar height to the smaller ones. The largest complex, at Kilamope, covers 10 ha and includes a 140 m by 40 m monumental platform (4.5 m high).

This pattern is repeated almost evenly throughout the area. Average density is 16.6 platforms/km^2, but some agglomerated areas have densities of >100 features/km^2. Because of their ubiquity and close relationship with the road network, we consider the complexes to be the elementary built features of the pre-Hispanic landscape.

Settlements

The distribution of elements in the study area reflects a settlement pattern in which the buffer zones between residential architectures played an important role. Moreover, clustering trends occur. Clusters of complexes have been identified as settlements on the basis of three criteria: feature density, size of the civic-ceremonial platforms, and connections with other complexes.

Fifteen settlements were classified into two categories: five major sites (large and/or dense centers) and 10 secondary sites (Fig. 1). Among the first group, Sangay stands out for its higher density (>125 platforms/km^2) and its ostentatious core. Accessed by a 2.5-km-long straight road, it lies at the highest point of the cliff that borders the Upano's northern bank, thus dominating the valley. Junguna and Kunguints seem to be chiefly residential sites with many small complexes adjoining intrasite circulation axes, whereas Kilamope and Copueno are characterized by large civic-ceremonial complexes.

Despite the apparent architectural and spatial homogeneity among these sites, several elements suggest that the settlements were exposed to threats. These include peripheral ditches blocking access to some settlements (e.g., east of Sangay) and obstructed roads near some large complexes (e.g., Copueno). We interpreted these elements as the result of tensions between groups or reinforcement of the sites against external threats.

Modified hills

Numerous "truncated" hills—natural reliefs with flat summits—were detected. While their general morphology is probably of volcanic origin (hummocks), a plausible hypothesis, supported by the accesses built on their slopes, is that their flattening is artificial, so that they constitute an integral component of the pre-Hispanic landscape (*41*).

Roads and pathways

Perhaps the most notable elements of the landscape are the intrasite pathways and a regional-scale intersite road network (Fig. 4). Roads are considered as such because they systematically link complexes (thus distinguishing them from other features, such as canals, described below). Some of these complexes, unusually isolated in the landscape, adjoin major roads as if they were layover points along the way.

Four types of roads or pathways have been identified. Although we cannot totally discount the possibility that a few paths could be the result of usage (sunken lanes) (*42*, *43*), the morphology of the features detected (e.g., rectilinearity, depth, curbs) strongly suggests that these are excavated roads. Therefore, the generic term "dug roads" is used here.

The most widespread are the straight-dug footpaths and roads (thus classified on the basis of their size and length) whose morphology is documented by fieldwork (*27*). Essentially straight and about 2 to 3 meters deep on average, they probably result from digging and accumulating earth on either side of the path, creating a U-shaped profile bordered by curbs. The width is 4 to 6 m for the smallest paths and up to >15 m for the largest ones, creating a walkable surface that is 2 to 5 m wide in the middle. Despite discontinuities in their layout owing to the heterogeneity of the LIDAR coverage, we can reasonably estimate that the longest roads—Uyunts-Jurumbuno and Kilamope-Kunguints—run for more than 14 and 25 km, respectively. Both are likely to continue beyond the boundaries of the study area. We believe that dug roads were designed to be as straight as possible despite the natural irregularities of the terrain.

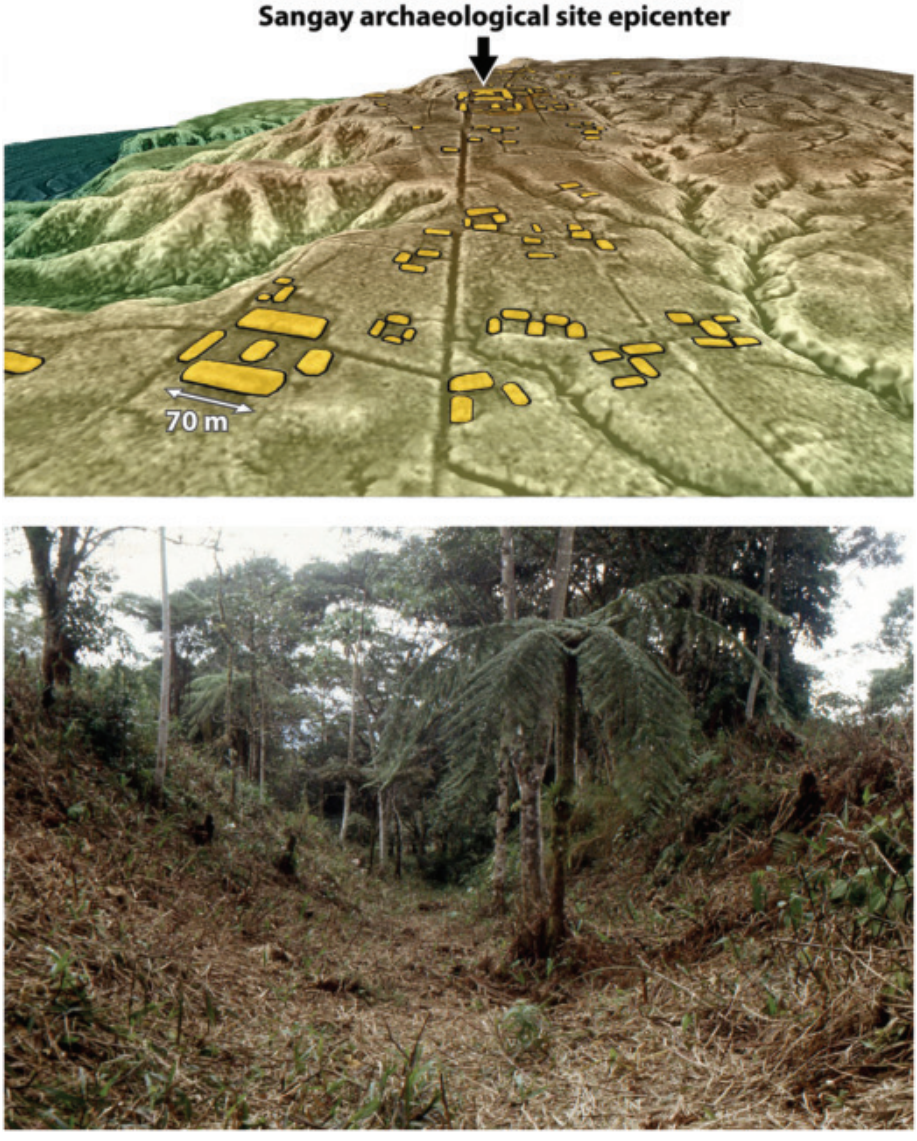

Fig. 4. Dug roads. Wide and deep dug roads connecting Upano monumental settlements.

The second type includes roads running along the interfluve in hilly terrain. Occasionally also dug, they follow topographic relief and connect open spaces (e.g., plateaus, riverbeds) through steep areas, such as the Andean footslopes or the valley cliffs. The third category includes possible elevated causeways with parallel ditches on either side of the road reminiscent of "causeways-canals" in the Llanos de Mojos of Bolivia (*44*). Finally, dug footpaths regularly end with a descent into one of the gullies (or quebradas) that spread on the Upano alluvial terrace and come out of the same gully a few hundred meters further on. This seems to constitute a fourth type of path, which takes advantage of the natural layout of the quebradas. In line with this, we argue that, beyond connecting spaces, most pathways were intimately related to surface water management and agricultural practices.

Drained fields and terraces

The LIDAR survey highlighted numerous agrarian features of two main types: drained fields and terraces. Their strong spatial coherence with the rest of the detected remains and, conversely, their location under forested areas support the inference that they were an integral part of the pre-Hispanic anthropogenic landscape.

Drained fields extend over hundreds of hectares into orthogonal and continuous plot systems (Fig. 2). The elementary unit is a rectangular field 10 to 40 m wide and several dozens of meters long. The field limits are ditches of 4-m width and 40-cm depth on average. They are connected to drainage canals, slightly wider and deeper, and mitigate waterlogging in this climate with daily rainfall. These canals then flow into the hydrographic network of the quebradas, whose course has sometimes been modified.

Drained fields are linked to the network of dug footpaths often surrounding them, making it sometimes difficult to distinguish between a road and a canal. In such cases, a clear connection to a complex was the discriminating criterion. However, it is very likely that pathways had a dual function of circulation and water management. This agricultural technique resembles those documented for the Llanos de Mojos in Bolivia and is still used today, for example, by the Karinya of the Orinoco llanos (*45*). Less widespread, terraces are found occasionally along the edges of quebradas, along the alluvial terrace of the Upano, perpendicular to concave hillslopes or on the lower Andean slopes, where they are associated with drains parallel to the slope.

Agrarian features fill the "gaps" between complexes and settlements noted during the first reading of the LIDAR data. Their ubiquity, their close connection with residential and ceremonial areas, and the variety of geomorphological contexts exploited demonstrate the importance of agricultural activity in the settlement pattern.

Discussion and conclusions

The results of fieldwork and LIDAR analysis demonstrate that the Upano Valley was densely populated around the beginning of the common era. The intimate link between residential and agricultural areas brings to mind the "garden cities" and "green urbanism" described or theorized by other researchers (*13*, *46*–*52*). Far from the utopia that these terms imply, however, the garden urbanism of the Upano valley constitutes a concrete, dynamic, and probably contested landscape and provides further proof that Amazonia is not the pristine forest once depicted.

The settlement pattern is composed of dense sites with standardized domestic groups of platforms around plazas and monumental civic architecture connected by streets. Establishments are linked to each other over great distances by a vast network of roads intertwined with intensive agricultural layouts. The organizational and architectural homogeneity, as well as the consistent interweaving of monumental-ceremonial features, domestic spaces, and economic areas, strongly suggests that the whole network was at least partly contemporary.

Despite variations in the settlement density, it must be emphasized that few areas of the valley are devoid of remains. Apparent empty buffer zones between complexes of platforms were in fact dedicated to agriculture. Two main patterning strategies have been recognized

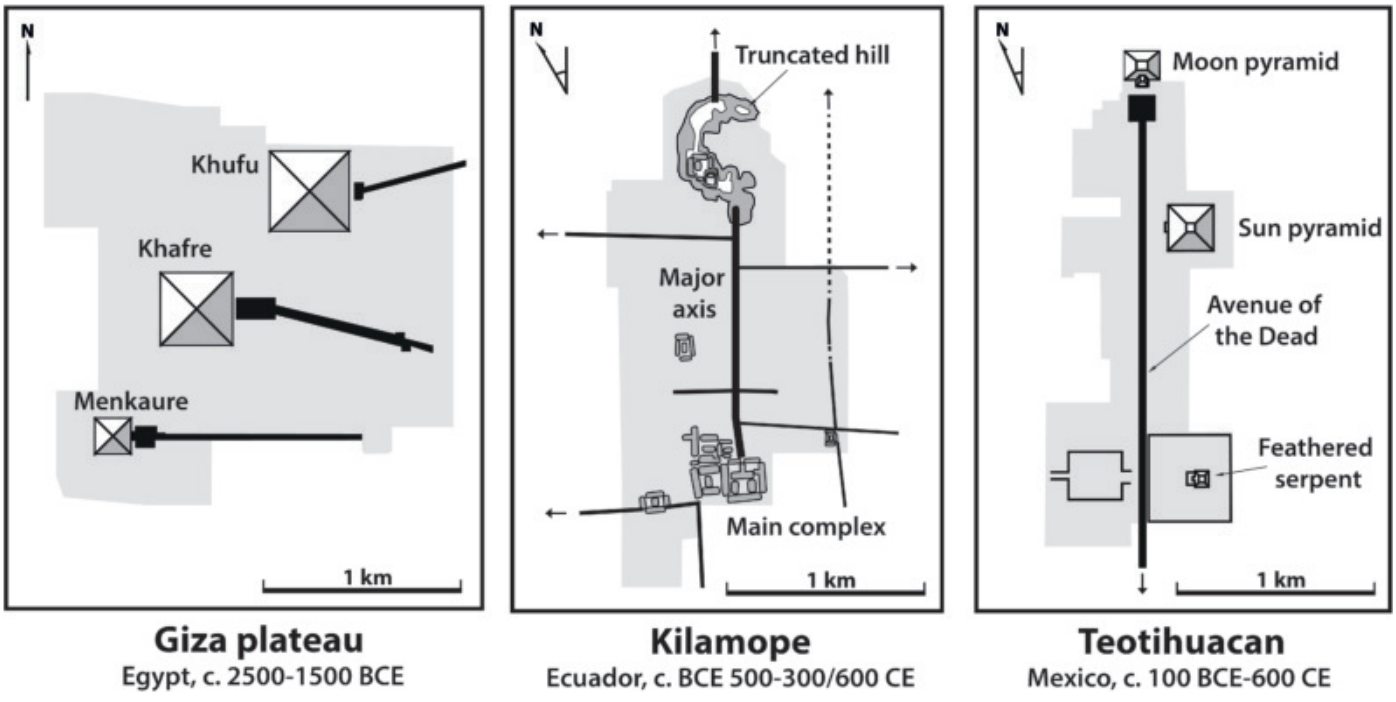

Fig. 5. Comparison of site sizes. Comparison at the same scale of the core areas of major sites of the Upano, ancient Egypt, and ancient Mesoamerica (for comparison with low-density urbanism sites in Amazonia, see supplementary text S4 and fig. S12).

and were seemingly induced by the valley's geomorphology. In the southern part of the study area, extensive parcels of drained fields are spread within a low-density distribution of complexes in the wetlands of the Upano alluvial terraces. Meanwhile, the hilly terrain of the northern zone is more prone to the clustering of complexes, with agricultural terraces intertwined with this denser grid in a more opportunistic manner. However, these two contrasting "environment-forced" sectors are all connected by the road network and its orthogonal layout, independent of all geomorphic constraints and constituting perhaps the most distinctive characteristic of this built landscape. Straight roads cross at right or nearly right angles without deviating in front of hills or ravines. If these roads facilitated exchanges, it is very likely that they also had a marked symbolic and powerful ritual function and participated in the construction of a cultural landscape. The complexity and dynamic nature of the latter are further demonstrated by the presence of defensive features that raise the question of alliances and tensions or possibly even episodic wars.

However, it would be imprudent to infer that these cities were organized around a centralized authority capable of mobilizing labor in a more or less coercive manner. The interlocking of groups of filiation and segmental solidarities, regularly reinforced by ceremonial exchanges, are sufficient to ensure the cohesion and coordination necessary for the organization of a highly structured settlement. Contemporary ethnology shows that exchanges are not so much based on economic logic as on the circulation of specialized production within ethnic confederations, each defining a local identity (*53*–*55*). Indeed, the overall organization and standardization of architectural features, the road patterns, or the defense systems, suggests, for instance, the existence of advanced engineering (mature architectural tradition relying on sighting and surveying instruments and/or expertise).

The Upano sites are quite different from other monumental sites of Amazonia, which are all more recent, considerably less dense in terms of features, and, until proven otherwise, not embedded in such a vast and dense communication network (fig. S12) (*13*, *14*). This original 2000-year-old society of the Upano valley constitutes the earliest and largest low-density agrarian urbanism ever documented in the Amazon so far. At a supraregional level, beyond exchanges with the Cuenca area, the relations and potential bilateral influence with the contemporary Andean world, such as Chavín de Huántar's sphere of influence (*56*, *57*), remain difficult to grasp (*58*, *59*). Yet, at present, there is no reason to believe that this is not an endogenous development.

The Upano's LIDAR coverage confirms the exceptional archaeological potential of Amazonia, recently recalled by extrapolative modeling in Brazil (*60*). However, whereas the latter article focuses on isolated earthworks (i.e., monumental ditches), the Upano materialized another scale of landscape anthropization, where urbanism covers hundreds of square kilometers. It echoes more clearly the Upper Xingu, where road networks suggest a low-density pre-Hispanic urbanism (*52*). This suggests that, being denser and less accessible, northern Amazonia may have been underestimated in terms of archaeological potential and promises numerous discoveries with future exploratory work and LIDAR coverage. Broadening perspectives, considering the region-scale density of features, the population density they must have supported, or the highly anthropized landscape—and although the size of the valley does not rival that of the Yucatán biosphere reserves—the human investment in the Upano Valley is comparable to that of contemporary Central Maya Lowlands (*61*–*65*). Going further, the major ceremonial cores, with monumental platforms, plazas, and causeways, are comparable in size to those of other great cultures of the past, such as Mexican Teotihuacan or the Egyptian Giza Plateau (Fig. 5).

What is very noteworthy is that this example of garden urbanism appears to be associated with a mound-building tradition. One wonders whether such architecture might echo other regions of the Americas and a pre-Hispanic ideology wherein fertility, origin of humanity, and ancestors are key aspects. Although the design of roads and canals is not radial in the Upano Valley, the grid it establishes is reminiscent of the ceque system of Cuzco (*66*)

and its connections between kin-based and segmented territories, ritual places of worship, and human-built hydraulic features. Indeed, it is tempting to see the Upano valley's geometrical layout, which cuts across the topography, as a cosmological design rather than a common and practical system of communication. This strong emphasis on abstract lineal connections between sites is more reminiscent of the sacred topography of Andean polities as "analogist" systems than of contemporary "animist" cultures of the Upper Amazon [in the sense of Descola (*67*)]. For lack of ethnographic analogies in settlement patterns in the contemporary lowlands, one should probably look for current highlands autochthonous polities whose sociocosmic structure is embedded in a topographical grid [for instance, the Chipaya of Bolivia (*68*)]. Such a discovery is another vivid example of the underestimation of Amazonia's twofold heritage: environmental but also cultural, and therefore Indigenous. Like many others (*69*–*71*), we believe that it is crucial to thoroughly revise our preconceptions of the Amazonian world and, in doing so, to reinterpret contexts and concepts in the necessary light of an inclusive and participatory science.

REFERENCES AND NOTES

1. G. de Carvajal, *Descubrimiento del río de la Amazonas* (Estudios ediciones y medios, Sevilla, [1542] 1992).
2. U. Lombardo *et al*., *Nat. Commun.* **13**, 3444 (2022).
3. S. Rostain, *Islands in the Rainforest: Landscape Management in Pre-Columbian Amazonia* (Left Coast Press, 2012).
4. S. Rostain, C. Jaimes Betancourt, Eds., *Las Siete Maravillas de la Amazonia precolombina* (IV Encuentro Internacional de Arqueología Amazónica, Bonner Altamerika-Sammlung und Studien, Plural Editores, 2017).
5. E. M. Redmond, C. S. Spencer, *Anthropol. Pap. Am. Mus. Nat. Hist.* **2007**, 86 (2007).
6. U. Lombardo, H. Prümers, *J. Archaeol. Sci.* **37**, 1875–1885 (2010).
7. M. J. Heckenberger *et al*., *Science* **301**, 1710–1714 (2003).
8. M. Heckenberger, *The Ecology of Power: Culture, Place, and Personhood in the Southern Amazon, AD 1000-2000* (Routledge, 2005).
9. E. Neves, *Sob os tempos do equinócio: Oito mil anos de história na Amazônia central* (Ubu Editora, 2022).
10. J. Iriarte *et al*., *J. Comput. Appl. Archaeol.* **3**, 151–169 (2020).
11. S. Saunaluoma, J. Moat, F. Pugliese, E. G. Neves, *Lat. Am. Antiq.* **32**, 1–15 (2020).
12. W. Denevan, *Cultivated Landscapes of Native Amazonia and the Andes* (Oxford Univ. Press, 2001).
13. M. J. Heckenberger *et al*., *Science* **321**, 1214–1217 (2008).
14. H. Prümers, C. J. Betancourt, J. Iriarte, M. Robinson, M. Schaich, *Nature* **606**, 325–328 (2022).
15. C. R. Clement *et al*., *Proc. R. Soc. London Ser. B* **282**, 20150813 (2015).
16. W. Balée, T. Swanson, M. G. Zurita-Benavides, J. C. Ruiz Macedo, *Lat. Am. Antiq.* **34**, 1–15 (2023).
17. P. Porras, *Natl. Geogr. Res.* **5**, 374–381 (1989).
18. S. Rostain, *Bull. Inst. Fr. Études Andines* **28**, 53–89 (1999).
19. D. Legrand *et al*., in *La cuenca oriente: Geología y petróleo*, P. Baby, M. Rivadeneira, R. Barragán, Eds. (IFEA, IRD, Petroecuador, 2004), pp. 168–182.
20. S. Bès de Berc *et al*., in *La cuenca oriente: Geología y petróleo*, P. Baby, M. Rivadeneira, R. Barragán, Eds. (IFEA, IRD, Petroecuador, 2004), pp. 153–167.
21. L. Rampón, in *Cuadernos de Investigaciones Científicas No. 1* (Arqueología, Misiones Católicas de la Amazonía, 1959).
22. P. Porras, *Natl. Geogr. Res.* **5**, 374–381 (1989).
23. P. Moncayo Echeverría, *Revista Sarance* **20**, 147–154 (1994).
24. A. Rostoker, thesis, City University of New York (2005).
25. P. Porras, *Investigaciones arqueológicas a las faldas del Sangay, Tradición Upano* (Centro de Investigaciones Arqueológicas, Universidad Católica del Ecuador, 1987).
26. E. Salazar, in *Handbook of South American Archaeology*, H. Silverman, W. Isbell, Eds. (Springer, Kluwer, Plenum, 2008), pp. 263–278.
27. S. Rostain, *STRATA* **1**, e2 (2023).
28. J. R. Pagán Jiménez, S. Rostain, "Uso de plantas económicas y rituales (médicinales o energizantes) en dos comunidades precolombinas de la Alta Amazonía ecuatoriana: Sangay (Huapula) y Colina Moravia (400 a.C.-1200 d.C.)" in *Antes de Orellana. Actas del 3er Encuentro Internacional de Arqueología Amazónica*, S. Rostain, Ed., IFEA, FLACSO, Embajada de los EEUU, Quito (2014), pp. 313–322.
29. S. Rostain, in *Cerâmicas Arqueológicas da Amazônia: Rumo a uma nova síntese*, C. Barreto, H. Lima, C. Jaimes Betancourt, Eds. (MPEG, Belém-do-Pará, 2016), pp. 573–585.
30. K. Bruhns, J. H. Burton, A. Rostoker, in *En Tecnología y organización de la producción de cerámica prehispánica en los Andes*, I. Shimada, Ed. (PUCP, Fondo Editorial, 1994), pp. 53–66.
31. C. Von Hillebrandt, in *El paisaje volcánico de la sierra ecuatoriana*, P. Mothes, Ed., vol. 4 of Estudios de Geografía (Corporación Editora Nacional, Colegio de Geógrafos del Ecuador, 1991), pp. 39–53.
32. M. Monzier *et al*., *J. Volcanol. Geotherm. Res.* **90**, 49–79 (1999).
33. L. Siebert, *J. Volcanol. Geotherm. Res.* **22**, 163–197 (1984).
34. V. Valverde, P. A. Mothes, B. Beate, J. Bernard, *J. Volcanol. Geotherm. Res.* **411**, 107172 (2021).
35. Technoproject, "Informe del levantamiento aéreo y del análisis preliminar e identificación de las anomalías del relieve relacionadas con las estructuras arqueológicas. Superficie Upano–Mera," field report, INPC, Quito (2015).
36. A. Sánchez-Polo, R. Á. Litben, *STRATA* **1**, e3 (2023).
37. S. Rostain, in *Communities in Contact. Essays in Archaeology, Ethnohistory and Ethnography of the Amerindian Circum-Caribbean*, C. L. Hofman, A. van Duijvenbode, Eds. (Sidestone Press, 2011), pp. 455–475.
38. S. Rostain, *Quat. Int.* **249**, 31–42 (2012b).
39. Z. Kokalj, R. Hesse, *Airborne Laser Scanning Raster Data Visualization: A Guide To Good Practice*, vol. 14 of Prostor, kraj, čas (Založba ZRC, 2017).
40. A. Dorison, C. Siebe Grabach, M. Elliott, G. Pereira, *Boletín de la Sociedad de Geología Mexicana* **74**, A180622 (2022).
41. G. de Saulieu, S. Rostain, J.-L. Le Pennec, "El Formativo del Alto Pastaza (Ecuador), entre arqueología y vulcanología" in *Antes de Orellana. Actas del 3er Encuentro Internacional de Arqueología Amazónica*, S. Rostain, Ed., IFEA, FLACSO, Embajada de los EEUU, Quito (2014), pp. 199–205.
42. M. Cardale de Schrimpff, *Caminos prehispánicos en Calima* (Fundación de Investigaciones Arqueológicas Nacionales, Santafé de Bogotá, 1996).
43. N. Nir *et al*., *Catena* **215**, 106312 (2022).
44. C. L. Erickson, in *Landscapes of Movement: Trails, Paths, and Roads in Anthropological Perspective*, J. E. Snead, C. L. Erickson, J. A. Darling, Eds. (Univ. of Pennsylvania Press, 2011), pp. 204–231.
45. W. M. Denevan, K. H. Schwerin, *Antropológica* **50**, 3–91 (1978).
46. E. Howard, *Garden Cities of Tomorrow* (2007).
47. C. M. Arensberg, in *Urban Life: Readings in Urban Anthropology*, G. Gmelch, W. P. Zenner, Eds. (St. Martin's Press, 1980), pp. 37–47.
48. W. J. Eggeling, *J. Ecol.* **34**, 20–87 (1947).
49. E. Graham, *Archeol. Pap. Am. Anthropol. Assoc.* **9**, 185–194 (1999).
50. C. Isendahl, M. E. Smith, *Cities* **31**, 132–143 (2013).
51. D. Marken, M. C. Arnauld, Eds., *Building an Archaeology of Maya Urbanism: Planning and Flexibility in the American Tropics* (Univ. Press of Colorado, 2023).
52. M. Heckenberger, in *Landscapes of Preindustrial Urbanism*, G. Farhat, Ed. (Dumbarton Oaks Research Library and Collection, 2020), pp. 225–262.
53. J. Jackson, *The Fish People: Linguistic Exogamy and Tukanoan Identity in the Northwest Amazon* (Cambridge Univ. Press, 1983).
54. P. Descola, *In the Society of Nature* (Cambridge University Press, 1994).
55. B. Franchetto, M. Heckenberger, Eds., *Os povos do Alto Xingu - história e cultura* (UFRJ, 2001).
56. R. L. Burger, *Chavin and the Origins of Andean Civilization* (Thames & Hudson, 1992).
57. R. L. Burger, in *Handbook of South American Archaeology*, H. Silverman, W. H. Isbell, Eds. (Springer, 2008), pp. 681–703.
58. A. J. Pearce, D. G. Beresford-Jones, P. Heggarty, Eds., *Rethinking the Andes-Amazonia Divide: A Cross-Disciplinary Exploration* (UCL Press, 2020).
59. R. Clasby, J. Nesbitt, Eds., *The Archaeology of the Upper Amazon: Complexity and Interaction in the Andean Tropical Forest* (Univ. Press of Florida, 2021).
60. V. Peripato *et al*., *Science* **382**, 103–109 (2023).
61. R. Fletcher, *Insights* **2**, 1–19 (2009).
62. A. F. Chase, D. Z. Chase, *Annu. Rev. Anthropol.* **45**, 361–376 (2016).
63. E. Lemonnier, in *Settlement Ecology of the Ancient Americas*, L. C. Kellett, E. E. Jones, Eds. (Routledge, 2017), pp. 167–194.
64. M. A. Canuto *et al*., *Science* **361**, eaau0137 (2018).
65. T. Beach *et al*., *Proc. Natl. Acad. Sci. U.S.A.* **116**, 21469–21477 (2019).
66. T. Zuidema, *The Ceque System of Cuzco: The Social Organization of the Capital of the Inca* (Brill, 1964).
67. P. Descola, *Beyond Nature and Culture* (Univ. of Chicago Press, 2013).
68. N. Wachtel, *Le retour des ancêtres. Les Indiens Urus de Bolivie, XX°-XVI° siècle. Essai d'histoire régressive*, Bibliothèque des sciences humaines (Éditions Gallimard, 1990).
69. C. Gnecco, P. Ayala, Eds., *Indigenous Peoples and Archaeology in Latin America* (Left Coast Press, 2011).
70. B. C. da Rocha, thesis, Institute of Archaeology, University College London (2017).
71. P. Erikson, V. Vapnarsky, Eds., *Living Ruins: Native Engagements with Past Materialities in Contemporary Mesoamerica, Amazonia, and the Andes* (Univ. Press of Colorado, 2022).

ACKNOWLEDGMENTS

LIDAR images were provided thanks to an agreement elaborated by J. F. Moscoso Novillo (director of the Ecuadorian National Institute for Cultural Heritage). The following persons helped during the fieldwork conducted by S.R.: I. Cangas, P. Baby, R. Bartone, S. Bes de Berc, J. Burgos, T. Bray, J. Burton, A.M.F., F. Fuentes, Y. Graber, J.-L.L.P., K. Olsen Bruhns, L. Pintér, P. Podwojewski, H.P., A. Rostoker, G.d.S., L. Zlonay, and several Ecuadorian and French students. Local people also contributed, especially J. Vega, Juan Vele, Julio Vele, and several workers. A. Gómez de la Peña, K. Leonard, and J.R.P.-J. did the archaeobotanical analyses. Thanks to D. McKey and F. Savatier for their reading and corrections and to the reviewer for their suggestions. **Funding:** This work was supported by the French National Center for Scientific Research (CNRS), Laboratory "Archaeology of the Americas" (UMR8096), French Ministry for Europe and Foreign Affairs (MAEE), French National Research Institute for Sustainable Development (IRD), German Kommission für Archäologie Außereuropäischer Kulturen (KAAK), Ecuadorian National Institute for Cultural Heritage (INPC), Banco Central del Ecuador, and National Secretary of Higher Education, Science, Technology and Innovation (SENESCyT). **Author contributions:** Conceptualization: S.R. and A.D. Methodology: S.R., A.D., H.P., and J.-L.L.P. Investigation: S.R., A.D., G.d.S., H.P., J.-L.L.P., F.M.M., A.M.F., J.R.P.-J., and P.D. Visualization: S.R., A.D., and H.P. Funding acquisition: S.R., G.d.S., H.P., and J.-L.L.P. Project administration: S.R. Supervision: S.R. Writing – original draft: S.R., A.D., G.d.S., H.P., J.-L.L.P., and P.D. Writing – review & editing: S.R., A.D., G.d.S., H.P., J.-L.L.P., and P.D. **Competing interests:** The authors declare that they have no competing interests. **Data and materials availability:** All data are available in the main text or the supplementary materials.

SUPPLEMENTARY MATERIALS

science.org/doi/10.1126/science.adi6317
Materials and Methods
Figs. S1 to S13
Tables S1 to S3
References

Submitted 10 May 2023; accepted 15 November 2023
10.1126/science.adi6317